



Section 2

Rational Formula



Rational Formula

$$Q = CIA$$

- ☛ Q = Runoff in cubic feet per second (cfs)
- ☛ C = Runoff coefficient (dimensionless)
- ☛ I = Rainfall intensity (inches per hour)
- ☛ A = Drainage area (acres)
- ☛ $1 \text{ cfs} = 1.008 \text{ acre-in/hr}$
 [\$\text{in/hr} \cdot \text{hr} / 3600 \text{ s} \cdot \text{ft} / 12 \text{ in} \cdot \text{acre} @ 43560 \text{ sf/acre}\$](#)

Runoff Coefficient (C)

Type of Cover	Flat	Rolling 2%-10 %	Hilly Over 10 %
Pavement and Roofs	0.90	0.90	0.90
Earth Shoulders	0.50	0.50	0.50
Drives and Walks	0.75	0.80	0.85
Gravel Pavement	0.50	0.55	0.60
City Business Areas	0.80	0.85	0.85
Suburban Residential	0.25	0.35	0.40
Single Family Residential	0.30	0.40	0.50
Multi Units, Detached	0.40	0.50	0.60
Multi Units, Attached	0.60	0.65	0.70
Lawns, Very Sandy Soil	0.05	0.07	0.10
Lawns, Sandy Soil	0.10	0.15	0.20
Lawns, Heavy Soil	0.17	0.22	0.35
Grass Shoulders	0.25	0.25	0.25
Side Slopes, Earth	0.60	0.60	0.60
Side Slopes, Turf	0.30	0.30	0.30
Median Areas, Turf	0.25	0.30	0.30
Cultivated Land, Clay and Loam	0.50	0.55	0.60
Cultivated Land, Sand and Gravel	0.25	0.30	0.35
Industrial Areas, Light	0.50	0.70	0.80
Industrial Areas, Heavy	0.60	0.80	0.90
Parks and Cemeteries	0.10	0.15	0.25
Playgrounds	0.20	0.25	0.30
Woodland and Forests	0.10	0.15	0.20
Meadows and Pasture Land	0.25	0.30	0.35
Pasture with Frozen Ground	0.40	0.45	0.50
Unimproved Areas	0.10	0.20	0.30

Figure 2-4.2
Runoff Coefficients for the Rational Method — 10-Year Return Frequency

25-yr increase C by 10%, 100-yr increase C by 25%
not to exceed 1.0

Rainfall Intensity (I)

In order to determine the rainfall intensity, first the travel time (T_t) for each of the basin segments must be calculated.

Travel Time

$$T_t = \frac{\Delta L}{K S^{0.5}} \quad \text{or} \quad = \frac{(\Delta L)^{1.5}}{K (\Delta H)^{0.5}}$$

where:

- T_t = Travel time for each basin segment (min)
- ΔL = Length of drainage basin in feet (m)
- K = Ground cover coefficient in ft/min (m/min)
- S = Average slope ($\Delta H/\Delta L$) in ft/ft (m/m)
- ΔH = Height of drainage basin in ft (m)

Next, the time of concentration (T_c) for the entire basin must be determined. The time of concentration is the time required for the surface runoff from the most remote part of the basin to reach the point of interest. It is equal to the sum of the individual travel times for each basin segment.

Time of Concentration

$$T_c = T_{t1} + T_{t2} + \dots + T_{tn}$$

The peak flow that occurs at the point of interest is produced by that rainfall intensity which is maintained for a time equal to the time of concentration. This occurs because at that particular time (equal to the T_c), the entire basin will be contributing runoff to the point of interest.

Rainfall Intensity (I)

Type of Cover		K (metric)	K (English)
Forest with heavy ground cover		50	150
Minimum tillage cultivation		75	280
Short pasture grass or lawn		125	420
Nearly bare ground		200	600
Small roadside ditch w/grass		275	900
Paved area		375	1,200
Gutter flow	100 mm deep	450	1,500
	150 mm deep	725	2,400
	200 mm deep	950	3,100
	300 mm diam.	925	3,000
	450 mm diam.	1,200	3,900
Storm Sewers	600 mm diam.	1,425	4,700
	300 mm deep	350	1,100
	600 mm deep	550	1,800
Open Channel Flow (n = .040)	1.20 m deep	850	2,800
Narrow Channel (w/d =1)	300 mm deep	600	2,000
	600 mm deep	950	3,100
	1.20 m deep	1,525	5,000
Open Channel Flow (n = .040)	300 mm deep	600	2,000
Wide Channel (w/d =9)	600 mm deep	950	3,100
	1.20 m deep	1,525	5,000

Figure 2-4.3
Ground Cover Coefficients

The equation for calculating rainfall intensity is:

$$I = \frac{m}{(T_c)^n}$$

where: I = Rainfall intensity in millimeters per hour (inches per hour in English units)

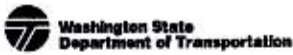
T_c = Time of concentration in minutes

m and n = Coefficients in dimensionless units (see Figures 2-4.4A and 2-4.4B)

Location	2-Year MRI		5-Year MRI		10-Year MRI		25-Year MRI		50-Year MRI		100-Year MRI	
	m	n	m	n	m	n	m	n	m	n	m	n
Aberdeen and Hoquiam	5.10	0.488	6.22	0.488	7.06	0.487	8.17	0.487	9.02	0.487	9.86	0.487
Bellingham	4.29	0.549	5.59	0.555	6.59	0.559	7.90	0.562	8.89	0.563	9.88	0.565
Bremerton	3.79	0.480	4.84	0.487	5.63	0.490	6.68	0.494	7.47	0.496	8.26	0.498
Centralia and Chehalis	3.63	0.506	4.85	0.518	5.76	0.524	7.00	0.530	7.92	0.533	8.86	0.537
Clarkston and Colfax	5.02	0.628	6.84	0.633	8.24	0.635	10.07	0.638	11.45	0.639	12.81	0.639
Colville	3.48	0.558	5.44	0.593	6.98	0.610	9.07	0.626	10.65	0.635	12.26	0.642
Ellensburg	2.89	0.590	5.18	0.631	7.00	0.649	9.43	0.664	11.30	0.672	13.18	0.678
Everett	3.69	0.556	5.20	0.570	6.31	0.575	7.83	0.582	8.96	0.585	10.07	0.586
Forks	4.19	0.410	5.12	0.412	5.84	0.413	6.76	0.414	7.47	0.415	8.18	0.416
Hoffstadt Cr. (SR 504)	3.96	0.448	5.21	0.462	6.16	0.469	7.44	0.476	8.41	0.480	9.38	0.484
Hoodport	4.47	0.428	5.44	0.428	6.17	0.427	7.15	0.428	7.88	0.428	8.62	0.428
Kelso and Longview	4.25	0.507	5.50	0.515	6.45	0.519	7.74	0.524	8.70	0.526	9.67	0.529
Leavenworth	3.04	0.530	4.12	0.542	5.62	0.575	7.94	0.594	9.75	0.606	11.08	0.611
Moses Lake	2.61	0.583	5.05	0.634	6.99	0.655	9.58	0.671	11.61	0.681	13.63	0.688
Mt. Vernon	3.92	0.542	5.25	0.552	6.26	0.557	7.59	0.561	8.60	0.564	9.63	0.567
Naselle	4.57	0.432	5.67	0.441	6.14	0.432	7.47	0.443	8.05	0.440	8.91	0.436
Olympia	3.82	0.466	4.86	0.472	5.62	0.474	6.63	0.477	7.40	0.478	8.17	0.480
Omak	3.04	0.583	5.06	0.618	6.63	0.633	8.74	0.647	10.35	0.654	11.97	0.660
Pasco and Kennewick	2.89	0.590	5.18	0.631	7.00	0.649	9.43	0.664	11.30	0.672	13.18	0.678
Port Angeles	4.31	0.530	5.42	0.531	6.25	0.531	7.37	0.532	8.19	0.532	9.03	0.532
Poulsbo	3.83	0.506	4.98	0.513	5.85	0.516	7.00	0.519	7.86	0.521	8.74	0.523
Queets	4.26	0.422	5.18	0.423	5.87	0.423	6.79	0.423	7.48	0.423	8.18	0.424
Seattle	3.56	0.515	4.83	0.531	5.62	0.530	6.89	0.539	7.88	0.545	8.75	0.545
Sequim	3.50	0.551	5.01	0.569	6.16	0.577	7.69	0.585	8.88	0.590	10.04	0.593
Snoqualmie Pass	3.61	0.417	4.81	0.435	6.56	0.459	7.72	0.459	8.78	0.461	10.21	0.476
Spokane	3.47	0.556	5.43	0.591	6.98	0.609	9.09	0.626	10.68	0.635	12.33	0.643
Stevens Pass	4.73	0.462	6.09	0.470	8.19	0.500	8.53	0.484	10.61	0.499	12.45	0.513
Tacoma	3.57	0.516	4.78	0.527	5.70	0.533	6.93	0.539	7.86	0.542	8.79	0.545
Vancouver	2.92	0.477	4.05	0.496	4.92	0.506	6.06	0.515	6.95	0.520	7.82	0.525
Walla Walla	3.33	0.569	5.54	0.609	7.30	0.627	9.67	0.645	11.45	0.653	13.28	0.660
Wenatchee	3.15	0.535	4.88	0.566	6.19	0.579	7.94	0.592	9.32	0.600	10.68	0.605
Yakima	3.86	0.608	5.86	0.633	7.37	0.644	9.40	0.654	10.93	0.659	12.47	0.663

Drainage Area (A)

- Greatest accuracy for basins that are 100 acres (40 hectares) or less
- Can be used for basins up to 1000 acres (400 hectares)
- Basin size should not exceed the lower limit specified for USGS Regression Equations



Hydrology By The Rational Formula

SR	Project	
Calculated By		Date

EQUATIONS
$T_c = \frac{L}{K\sqrt{S}} = \frac{L^{1.5}}{K\sqrt{\Delta H}}$
$I = \frac{m}{(T_c)^n}$
$Q = \frac{CIA}{K_c}$

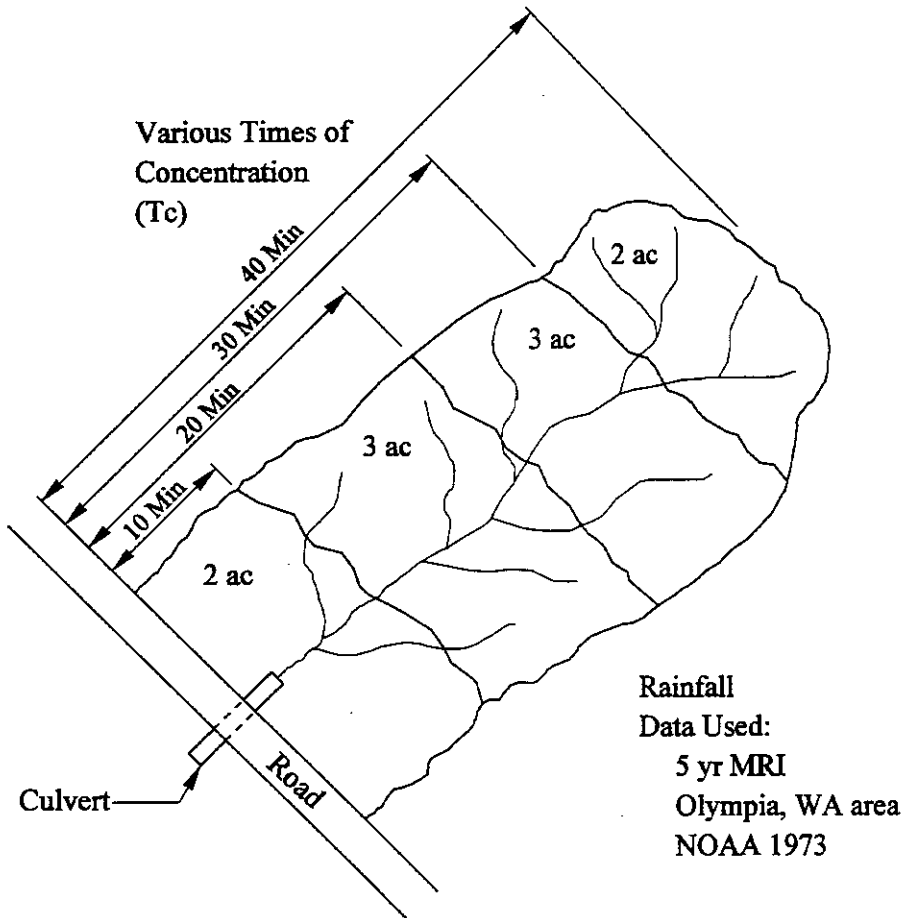
LEGEND	
Q = Flow	T_c = Time of concentration
L = Length of drainage basin	m & n = Rainfall coefficients
S = Average slope	K_c = Conversion factor
K = Ground cover coefficient	C = Runoff coefficient
ΔH = Change in elevation of basin	A = Drainage area

Figure 2-4.1
Hydrology by the Rational Method

Description Of Area	MRI	L	ΔH	S	K	T_c	Rainfall Coeff		K_c	C	I	A	Q
							m	n					

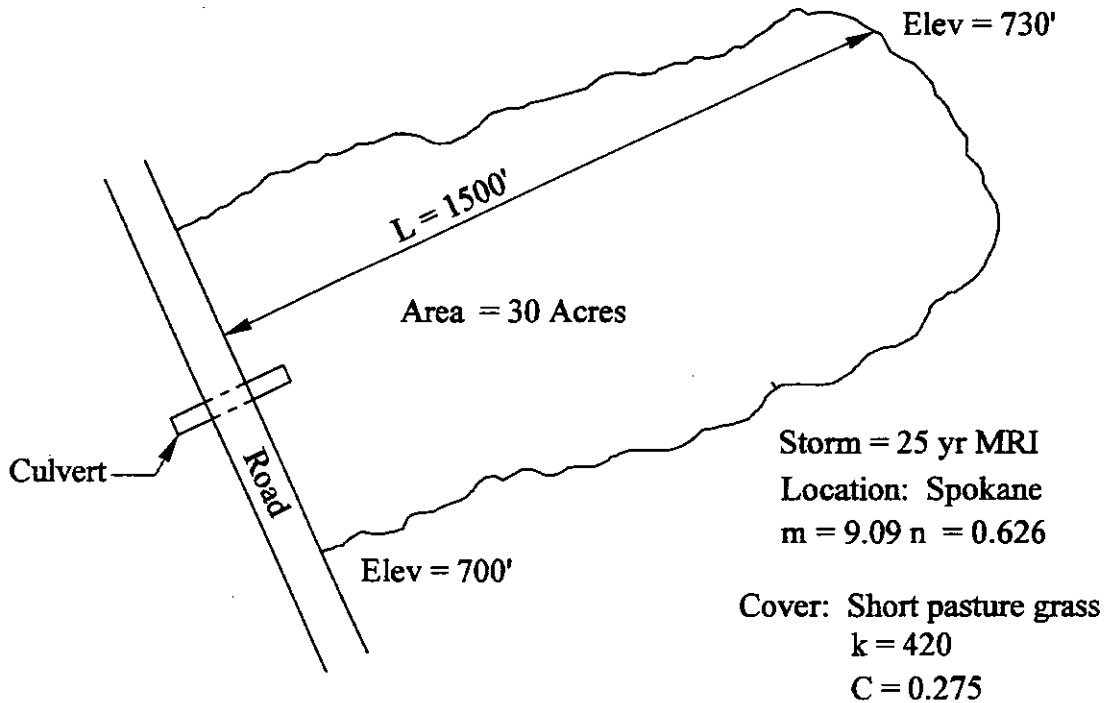
Rational Formula

Typical 10 Acre Drainage Basin



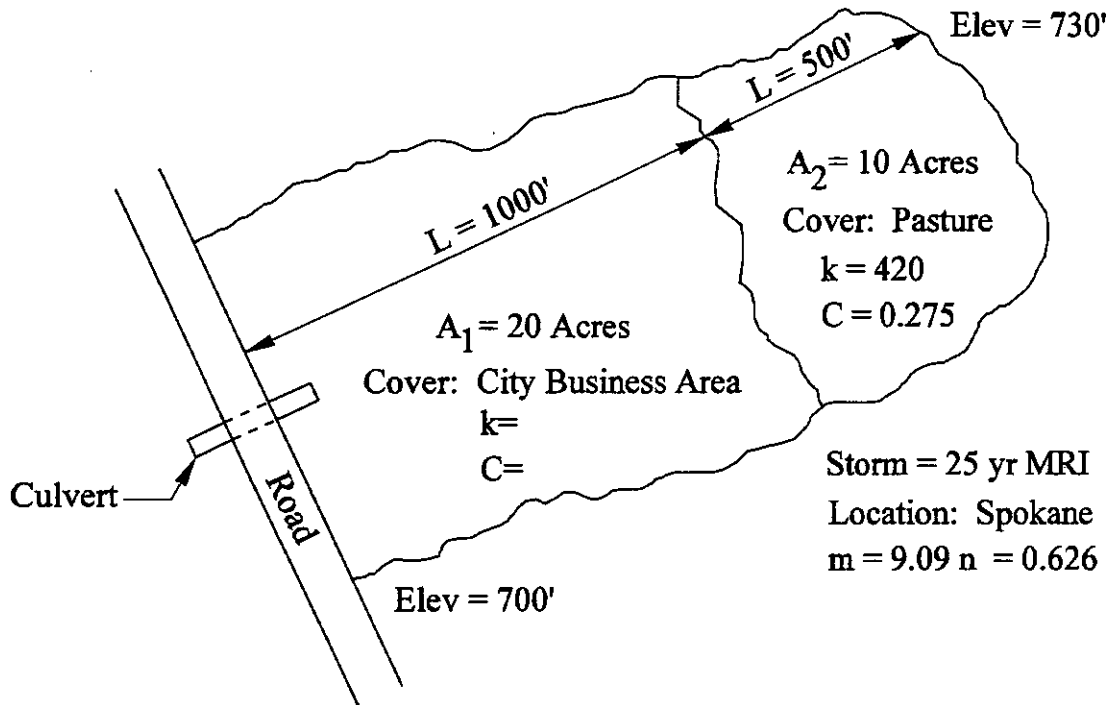
Rainfall Duration (Min)	Rainfall Intensity (in/hr)	C*A (Acres)	Q = CIA (cfs)
10	1.72	2	3.44
20	1.30	5	6.50
30	1.01	8	8.08
40	0.89	10	8.90
60	0.64	10	6.36
100	0.53	10	5.30
1440	0.16	10	1.61

Rational Formula Example



Determine the runoff Q that will occur in this basin.

Rational Formula Problem



Determine the runoff that will occur due to development in the basin. Assume that the city business area has paved and gutter flow.

Remember: $T_{c_{\text{basin}}} = T_{c_{A_1}} + T_{c_{A_2}}$

$$Q = (\sum CA)I = [C_1 A_1 + C_2 A_2] * I$$